DOCUMENT RESUME

ED 210 159 SE 035 835

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TITLE Cognitive Style in Students Evidencing Dyscalculia.
PUB DATE Nov 81
NOTE 27p.: Paper presented at the Annual Meeting of the Mid-South Educational Research Association (10th, Lexington, KY, November 11-13, 1981).

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Style; *Computation; Educational Research; Elementary Secondary Education; *Grade 7; Junior High Schools; *Learning Disabilities; *Mathematics Education; Sex Differences; Spatial Ability
IDENTIFIERS *Dyscalculia; Field Dependence; Field Independence; *Mathematics Education Research

ABSTRACT

The purpose of this study was to compare factors of cognitive style in two groups of seventh grade children: (1) children of average or above average intelligence who show learning disability in mathematics but who perform well in reading; and (2) children of average or above average intelligence who perform well in both mathematics and reading. Thirty students were chosen as subjects for each of the two groups. Results indicated that students evidencing dyscalculia were significantly different from their mathematically achieving counterparts on two factors of cognitive style: field dependence and independence, and spatial visualization. Significant sex differences were found in scores used to measure field dependency, and differences in high-level spatial visualization were also found. The investigation is thought to offer some explanation as to why some intellectually capable students were unable to achieve in mathematics. (MP)

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COGNITIVE STYLE IN STUDENTS EVIDENCING DYSCALCULIA

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Presented at the Tenth Annual Meeting
Mid-South Educational Research Association
November 11-13, 1981 Lexington, KY

SE 035 835

Introduction

Researchers have spent considerable time identifying special abilities or aptitudes, separate from general intelligence, that correlate positively with mathematics achievement (e.g. Aiken, 1971; Glaser, 1972; Pullman, 1979; Witkin, Moore, Goodenough, & Cox, 1977). One of the variables most prominently identified has been verbal ability. In a comprehensive research review, Aiken (1971) reported that a "common theme" throughout the studies investigating the relationship of intellectual factors and mathematics achievement was the existence of a significant, positive correlation between verbal ability and mathematics ability. It has also been shown that the correlation between reading test scores and mathematics test scores reflects more than just the overlap that these tests share with general intelligence measures (Cleland & Toussaint, 1962; Pitts, 1952), further substantiating the existence of special abilities that are separate from general intelligence.

Nevertheless, while mathematics ability and verbal ability are correlated highly, recent research has reported a particular population of children who demonstrate good verbal ability but who consistently perform poorly in mathematics (Weinstein, 1978). These are children whose inabilities are exclusively in the area of mathematics: They exhibit average or above average general intelligence, and they perform well in reading. Children so identified are defined operationally as dyscalculics, a disorder

of the abilities for learning about numbers and for computation that does not affect general intelligence (Kosc, 1974; Weinstein, 1978). Such children are not isolated cases: Preliminary data indicate that approximately 6% of our student population is so afflicted (Weinstein, 1978). Even though the mathematics performance of dyscalculics has been analyzed (Kosc, 1974; Weinstein, 1978), there has been almost no research on the cognitive style of these children as compared with the cognitive style of children who perform well in reading and mathematics.

Cognitive style is a psychological construct that has been explored increasingly in an attempt to explain individual variation in perception, problem solving, and learning. Much of the theoretical structure of the construct originated from the work of Kretch and Crutchfield (1948) in which they proposed that cognitive style, a dimension that is different from general intelligence, may explain the selectivity and organization that is inherent in the process of perception. Cognitive style, then, has been defined in terms of processes that determine the way an individual relates perception to higher order thinking and includes the cognitive activities of selecting, sorting, and organizing that impose structure on information (Santostefano, Rutledge, & Randell, 1965). Witkin et al. (1977) defined cognitive style as a "characteristic approach" an individual brings to a learning situation that "encompasses both his perceptual and intellectual activities" (p. 10). In an earlier and more general discussion of psychological differences,

Witkin (1967) stressed the importance of cognitive style to learning and stated that knowing a child's cognitive style can be as useful to educators as knowing a child's IQ (p. 36).

One of the factors of cognitive style that has been investigated by several researchers is the factor of field dependence/independence. As Witkin et al. (1977) stated, this factor is relatively stable and influences the way an individual interacts with his/her environment. Field dependence is determined by assessing the influence of the prevailing field with individual performance on perceptual tasks. An individual who cannot separate perceptually an item from the surrounding field is said to be field dependent; a person who can perceive the item as discrete from the surrounding field is said to be field independent. According to Adams and McLeod (1979):

> Individual differences in field dependence/independence are identified on a continuum determined by the extent a person perceives analytically. Students who are relatively field dependent find it difficult to restructure a situation in order to solve a problem or to impose structure on material when structure is lacking. On the other hand, field independent students are more capable of taking a critical element out of context and restructuring a problem in order to use that element in a different context. (p. 347)

Another dimension in cognitive style that appears to have a relationship to achievement in mathematics is spatial visualization. Studies by McDaniel and Guay (1976) support the concept that there are different levels of spatial ability and suggest a continuum for describing spatial ability that ranges from the ability to recognize and retain visual patterns to

more complex mental manipulation of visual images. Furthermore, McDaniel and Guay (1976) found that low-level as well as high-level spatial abilities correlated positively with mathematics achievement.

The hypothesis that males and females have different spatial abilities and, therefore, differential success in mathematics has also been investigated in several recent studies. Though there have been conflicting results in investigating sex-related differences in spatial ability, these studies have shown spatial ability to be positively correlated with achievement in mathematics (Brendzel, 1978; Fennema & Sherman, 1978; Maccoby & Jacklin, 1974; McDaniel & Guay, 2977; Sherman, 1979).

However, there is some inconsistency in prior research showing spatial ability and mathematics achievement to be positively correlated. Weinstein's study (1978) of dyscalculia did not find significant differences between the group of dyscalculic students and their controls on geometry problems which involved spatial tasks. This inconsistency merits further investigation.

Because the investigation of cognitive style has been a promising avenue of investigation for explaining learning differences, this research was conducted to investigate the cognitive style factors of field dependence/independence and low-level and high-level spatial visualization in students evidencing dyscalculia.

Statement of the Problem

The purpose of this study was to compare factors of

cognitive style in two groups of seventh grade children: (1) children of average or above average IQ who evidence learning disability in mathematics but who perform well in reading and (2) children of average or above average IQ who perform well in both mathematics and reading.

Methodology

Subjects

Subjects were selected from seventh-grade students in the Shelby County Alabama School System. Group membership was determined by students' IQ scores, by reading and mathematics scores on the California Achievement Test (CAT), and by consultation with the mathematics teachers. For the purposes of the study, students whose CAT grade equivalent mathematics scores were 6.2 or below, whose CAT reading scores were 8.0 or above, and whose IQ estimates were 95 to 125 were identified as dyscalculic. Group 1 was comprised of students evidencing dyscalculia. Group 2 was comprised of students whose IQ and reading scores were similar to those in Group 1, but who were performing above grade level in mathematics. Each group contained 30 students. However, 36 students initially qualified for membership in Group 2. In order to equalize the number of students in each group, 30 students were selected randomly from the 36.

Instrumentation

The instruments used in assessing cognitive style have been used previously in several studies (e.g., Adams & McLeod, 1979; Brendzel, 1978; McDaniel & Guay, 1977· McLeod, Carpenter, McCornach, & Skvarcius, 1978; Satterley, 1975). The Embedded

Figures Test (EFT) was used to assess field dependency. This test, developed by Herman A. Witkin in 1950, is an individually-administered, perceptual test that requires the subject to locate a simple figure that is embedded within a larger more complex figure.

The Mental Rotations Test (MRT), a group test of three-dimensional spatial visualization, was used to measure high-level spatial ability, the ability to visualize three-dimensional configurations and to mentally manipulate these configurations. The MRT was constructed from the figures used in an earlier study of mental imagery by Shepard and Metzler (1971).

The Card Rotations Test (CRT) was used to measure low-level spatial ability. This test, from the Kit of Factor-Referenced Cognitive Tests, was developed by Educational Testing Service from Thurstone's Cards to measure the factor "spatial orientation" (Ekstrom, French, & Harman, 1976). The CRT presents two-dimensional objects in rotation.

Data Collection

The EFT, MRT, and the CRT were administered to the selected subjects by the investigator during the spring of 1981. The group tests were given first, starting with the CRT and followed by the MRT. The EFT was administered last. All tests were scored by the investigator.

Data Analysis

In order to test group and sex differences, a two-way analysis of variance (ANOVA) was used to statistically compare

mean scores on the EFT, the CRT, and the MRT. This analysis was also used to determine if a significant group by sex interaction existed on these variables. Homogeneity of variance between groups was initially determined for each of the variables to affirm the appropriateness of ANOVA.

A group comparison of the proportion of students who were field independent was made using the chi square statistic. Because expected cell frequencies were small in this study, Yate's correction for continuity was applied to the statistic. This was deemed advisable since the continuous theoretical frequency curve of chi square may not provide a good fit to the data in such cases (Ferguson, 1976, p. 201). The corrected chi square was then used to determine statistical significance. The .05 level was used as the criterion for significance.

Results

The summary statistics that were used to compare salient characteristics of the two groups indicated similarities on age, IQ, and grade equivalent reading scores. Significant disparity between groups was shown on grade equivalent mathematics scores. Table 1 shows the characteristics of the sample.

Field Dependence/Independence

Scores on the Embedded Figures Test (EFT) were used to determine the dichotomous categories of the field dependency variable, i.e., field dependent or field independent. Reliability on the EFT computed from this data using Cronbach's coefficient alpha was .78.

Table 1

Characteristics of the Sample

Variable	Group 1		Group 2	
	Mean	SD	Mean	SD
Age (in months)	156.26	5.72	154.80	4.75
IQ	107.10	8.44	111.80	6.89
Grade equivalent reading score	8.7	1.33	9.0	.90
Grade equivalent mathematics score	5.6	.54	9.4	1.05

Field independence was defined as the relative ability to perceive an item as separate from the surrounding field or background as determined by scoring below the sample median score on the EFT. The sample median score was 69.00. This score was used as the division point for the dichotomous classification of field dependent or field independent.

Item scores on the EFT represented the time in seconds that it took a student to disembed a specified pattern from a complex background. The total test score for a student was the mean of the 12 item scores.

A group mean of 80.89 seconds was computed for Group 1, well

above the sample median score of 69.00 seconds. Group 2 had a mean score of 55.93 seconds. A breakdown of these data by sex as well as by group revealed consistent sex differences throughout: Males in each group required less time to complete EFT test items than did the females in that group. Table 2 presents these data.

Table 2

Embedded Figures Test Scores
Results by Group by Sex

Group	Means	SD	N
1	80.89	28.01	30
Males	71.41	26.28	18
Females	95.10	25.17	12
2	55.93	28.82	30
Males	49.43	29.73	18
Females	65.69	25.48	12

A two-way analysis of variance was used to investigate the relationship between the dependent variable, EFT scores, and the two independent variables, group and sex. A test for homogeneity of variance was nonsignificant (F_{max} = 1.058, df = 2, 29), thereby affirming a requisite assumption for analysis of variance. The analysis showed significant differences on the scores for both group and sex. This indicates that Group 1 required significantly more time than Group 2 to perceive a pattern as separate

from its background and was, therefore, more field dependent than Group 2. Females required significantly more time than males to complete this same task and; consequently, were more field dependent than males. The test statistic computed for group effects was F (1,56) = 12.799, p = .001; the test statistic for sex effects was F (1,56) = 7.868, p = .007. A nonsignificant F ratio was found for the sex by group interaction. The results of the analysis of variance are shown in Table 3.

The discrepancy between groups on the number of students classified as field independent was tested with the chi square statistic. The results showed a significant discrepancy between groups on this variable. Group 2, with 70% of its students classified as field independent, had a significantly greater proportion in this category than did Group 1 with 33.3%. The computed chi square was significant well beyond the preset .05 level (chi square = 6.67, df = 1, p = .0098). The degree of association between field dependency and groups given with the contingency coefficient was .344 (maximum = .707). These data are presented in Table 4. The results of this analysis strongly indicate a group difference on this factor of cognitive style and show Group 2 to be much more field independent than Group 1.

Spatial Visualization

Two levels of spatial visualization were assessed in this study. The CRT was used to measure a lower level ability, and the MRT was used to measure a higher level ability. The use of Cronbach's coefficient alpha gave the following reliabilities with the data from this study: CRT, .92; MRT, .87.

Table 3

Analysis of Variance Summary Table
Embedded Figures Test Sex by Group

Source	SS	df	MS	F	p
Main effects	15086.730	2	7543.365	10.334	.000
Sex	5743.447	1	5743.447	7.868	.007
Group	9343.283	1	9343.283	12.799	.001
Interaction	198.306	1	198.306	.272	.604
Explained	15285.035	3	5095.012	6.980	.000
Residual	40878.592	56	729.975		
Total	56163.627	59	951.926		

Table 4

Contingency Table Showing Relationship Between Groups and Field Dependence/Field Independence

	FD	FI	Total
Group 1	20 (66.7%)	10 (33.3%)	30 (100%)
Group 2	9 (30.0%)	21 (70.0%)	30 (100%)
Total	29 (48.3%)	31 (51.7%)	60 (100%)

Chi square = 6.67 (significant, $p = .0098$)

$df = 1$

Contingency coefficient = .34

Table 5 presents the mean scores on the CRT and the MRT by group and by sex within group. The maximum score possible on the CRT was 160, and 40 was the maximum score possible on the MRT. Group means on the CRT were higher for Group 2 than for Group 1 with means of 135.20 and 121.77 being computed for the two groups respectively. CRT scores showed a considerable sex-related difference favoring males in Group 2, but there was less than a one-point difference in scores by sex in Group 1.

MRT scores were also higher in Group 2. The mean score for Group 2 was 29.17 while the mean for Group 1 was 25.73. Sex-related differences favoring males were evident in both groups.

In fact, Group 2 females scored lower than Group 1 males and only exceeded the Group 1 mean score by .02. The sex ratio in each group was the same.

Table 5

Spatial Visualization Scores
Results by Group by Sex

Group	Card Rotations Test		Mental Rotations Test		N
	Means	SD	Means	SD	
1	121.77	18.07	25.73	5.42	30
Males	121.33	17.43	26.28	6.11	18
Females	122.42	19.77	24.92	4.32	12
2	135.20	17.60	29.17	5.31	30
Males	141.00	13.16	31.44	3.75	18
Females	126.50	20.30	25.75	5.61	12

A two-way analysis of variance was employed with each set of scores to determine the relationship between scores by group and by sex. With both sets of data, tests for homogeneity of variances indicated the necessary nonsignificant F_{max} = ratio (CRT: F_{max} = 1.054, df = 2,29; MRT: F_{max} = 1.041, df = 2,29).

Using the data from the CRT, Group 2 was shown to exhibit significantly greater low-level spatial visualization than Group 1. The significant F ratio for group effects was F (1,56) = 8.947, p = .004. The F ratio for sex differences was nonsignificant. No significant group by sex interaction was found. These

data appear in Table 6.

The analysis of the data from the MRT showed significant differences for both group and sex: Group 2 outperformed Group 1, and males outperformed females. The results indicate that Group 2 had significantly greater high-level spatial visualization ability than Group 1. It also appears that males had significantly greater high-level spatial visualization ability than females. No significant group by sex interaction was found. The F ratio for group effects was F (1,56) = 6.957, p = .011; the F ratio for sex effects was F (1,56) = 7.051, p = .01. These data are reported in Table 7.

The results of the analyses of the CRT group scores for low-level spatial visualization and the MRT group scores for high-level spatial visualization clearly show Group 2 to be superior to Group 1 in spatial visualization.

Conclusions and Discussion

The following conclusion was drawn from this study: students evidencing dyscalculia are significantly different from their mathematics achieving counterparts on two factors of cognitive style -- field dependence/independence and spatial visualization.

An investigation into the cognitive style factor of field dependency showed the dyscalculic group to be significantly more field dependent than their controls. Field dependency is an aptitude separate from IQ; therefore, the fact that such a difference existed between groups that did not differ sub-

Table 6

Analysis of Variance Summary Table
Card Rotation Test Scores Sex by Group

Source	SS	df	MS	F	p
Main effects	3354.842	2	1677.421	5.545	.006
Sex	648.025	1	648.025	2.142	.149
Group	2706.817	1	2706.817	8.947	.004
Interaction	874.225	1	874.225	2.890	.095
Explained	4229.067	3	1409.689	4.660	.006
Residual	16941.913	56	302.534		
Total	21170.980	59	358.830		

Table 7

Analysis of Variance Su
Mental Rotations Test Scor

Source	SS	df
Main effects	356.028	2
Sex	179.211	1
Group	176.817	1
Interaction	67.600	1
Explained	423.628	3
Residual	1423.222	56
Total	1846.850	59

mmary Table
es Sex by Group

	MS	F	p
	178.014	7.004	.002
	179.211	7.051	.010
	176.817	6.957	.011
	67.600	2.660	.109
	141.209	5.556	.002
	25.415		
	31.303		

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stantially on IQ is therefore more plausible.

However, field dependence apparently confers a very real disadvantage in performance with mathematics, and results from this study substantiate that assumption. Prior research has shown field dependent students to have difficulties in restructuring material or in using an element for problem solving out of the context in which it was presented. Both of these attributes are extremely important for achievement in mathematics.

On the other hand, students who are field independent have been shown to perceive more analytically, to have greater ability to impose structure on material, and to work more successfully under distracting circumstances. The more field dependent cognitive style of the dyscalculic student with its concomitant deficits in analytical and structuring abilities, then, would help explain the difference in mathematics performance between the two groups.

Scores on the EFT, used to assess field dependency, showed significant sex differences as well as group differences. These scores represented the time required for a student to perform the disembedding tasks on the test. Length of time on the test and field independence are inversely related. Males accomplished the tasks in significantly less time than females. Within both groups, the mean time for females was greater than for males. A discrepancy of more than 45 seconds per task was found between means of dyscalculic females and male controls.

Such sex differences on this factor of cognitive style, a factor which has been shown to be responsible for enabling a

person to organize material in a more analytical manner, strongly supports the finding of a recent study by Benbow and Stanley (1980). The study, involving approximately 10,000 mathematically precocious students found "sizable sex differences in mathematical reasoning ability in 7th grade students" favoring males (Benbow & Stanley, 1980, p. 1263).

The other factor of cognitive style investigated in this study was spatial visualization. Results showed the dyscalculic group to have significantly less low-level and high-level spatial visualization than Group 2. These findings are inconsistent with Weinstein's results (1978) in which no significant differences were found between dyscalculics and their controls on mathematics tasks involving spatial ability. However, the findings of this support the results found in a number of other studies (e.g., Guyer & Friedman, 1975; Maccoby & Jacklin, 1974; McDaniel & Guay, 1977) that indicate a positive correlation between spatial visualization and performance in mathematics. Once again, a deficit in this ability within the dyscalculic group helps explain group differences in mathematics achievement.

Sex differences in high-level spatial visualization were also found. Males scored significantly higher on the MRT than females; in fact, males in the dyscalculic group scored higher than females in Group 2. Consequently, females in Group 2 contributed little to group differences favoring this group on the MRT: Their mean MRT score was 25.75 and the Group 1 mean was 25.73. Because high-level spatial visualization correlates

positively with mathematics performance, these results also support the recent study by Benbow and Stanley (1980) in which they found "superior male mathematical ability, which may in turn be related to greater male ability in spatial tasks" (p. 1264).

In summary, this study found a cognitive style among dyscalculic students that makes them less able than other students of similar age and IQ to effectively recognize and structure mathematics concepts for problem solving. This appears to offer some explanation to the question that remains a challenge to educators: Why are some intellectually capable students unable to achieve in mathematics?

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